Hospital-Level Disparities in the Outcomes of Acute Myocardial Infarction With Cardiogenic Shock

Saraschandra Vallabhajosyula, MD, Shannon M. Dunlay, MD MS, Gregory W. Barsness, MD, Charanjit S. Rihal, MD, David R. Holmes, Jr, MD, and Abhiram Prasad, MD*

There are limited data on hospital-level disparities in cardiogenic shock complicating acute myocardial infarction (AMI-CS). A retrospective cohort of adult admissions from the National Inpatient Sample database during 2000 to 2014, with primary diagnosis of AMI and concomitant CS were identified. Interhospital transfers were excluded. Hospitals were classified into rural, urban nonteaching and urban teaching (location and teaching status) and small, medium and large (bedsize). The primary endpoint was in-hospital mortality and secondary endpoints included use of early coronary angiography, percutaneous coronary intervention (PCI) and mechanical circulatory support (MCS). Multivariable regression was used to adjust for potential confounding. During 2000 to 2014, 362,065 AMI-CS admissions met the inclusion criteria, of which 92% and 69% respectively were admitted to urban and large hospitals. Admissions to urban and large hospitals were more frequently male, younger, with lower co-morbidity, and higher illness severity. There was a steady increase in early coronary angiography, PCI and MCS across the various hospital categories. Admission to an urban nonteaching hospital (adjusted odds ratio [aOR] 0.81; 95% confidence interval [CI] 0.78 to 0.84], p <0.001) and urban teaching hospital (aOR 0.87 [95% CI 0.84 to 0.91, p <0.001) were associated with lower mortality compared with rural hospitals. In comparison to a small hospital, admission to a large hospital (aOR 0.94 [95% CI 0.91 to 0.98); p = 0.002) was associated with lower in-hospital mortality. Large and urban hospitals had greater use of early coronary angiography, PCI, MCS. In conclusion, there are hospital-level disparities in the management and outcomes of AMI-CS which are not fully accounted for differences in patient characteristics.   © 2019 Elsevier Inc. All rights reserved. (Am J Cardiol 2019;124:491−498)

Cardiogenic shock complicating acute myocardial infarction (AMI-CS) is seen in 6% to 10% of patients with AMI and remains a cause of high mortality and morbidity.[1,2] Observational studies of national cohorts of CS patients suggest that there is a hospital case volume-outcomes relationship suggestive of lower in-hospital mortality in higher volume centers.[3] There are few dedicated studies evaluating hospital-level disparities in the care of AMI-CS patients. Patients with AMI-CS are unique from other populations with CS in their sudden-onset, requirement for emergent revascularization and rapid development of multiorgan failure.[2,4] Patients with AMI-CS require intensive care management, and access to MCS and noncardiac organ support devices to optimize clinical outcomes.[5] Given the complexity of care and associated high costs, the management of CS merits further investigation, as there might be system-level variations with respect to clinical practice and outcomes.[4] Therefore, this study sought to evaluate the temporal trends and outcomes of AMI-CS admissions to hospitals stratified by location, teaching status and size from a nationwide database. We hypothesized that hospital size and location are markers of systems

of care and therefore would significantly influence outcomes independent of co-morbidity and acuity of patient presentation.

Methods

The National (Nationwide) Inpatient Sample (NIS) is the largest all-payer database of hospital inpatient stays in the United States. NIS contains discharge data from a 20% stratified sample of hospitals and is a part of the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality.[6] Information regarding each discharge includes patient demographics, primary payer, hospital characteristics, principal diagnosis, up to 24 secondary diagnoses, and procedural diagnoses. The HCUP-NIS does not capture individual patients but captures all information for a given admission/hospitalization.

Using the HCUP-NIS data from 2000 to 2014, a retrospective cohort study of admissions with AMI in the primary diagnosis field (International Classification of Diseases 9 Clinical Modification [ICD-9CM] code 410.x) with a secondary diagnosis of CS (ICD-9CM 785.51).[1,2] Validation studies have shown a specificity of 99.3%, a sensitivity of 59.8%, a positive predictive value of 78.8%, and a negative predictive value of 98.1% for the ICD-9-CM code 785.51 to identify CS.[7] Admissions transferred from other acute care hospitals were excluded since this might result in inaccurate estimations of hospital-level variation

of outcomes. The database provides demographic characteristics, primary payer, hospitals location and teaching status (classified as rural, urban non-teaching and urban teaching).[8] Individual hospitals are classified as small, medium and large based on the hospital bed count. Based on location, small hospitals were 1 to 250 beds, medium-sized were 50 to 450 beds and large hospitals were >50 to 450 beds (Supplementary Table 1).[8] The Deyo's modification of Charlson Co-morbidity Index was used to identify the burden of co-morbid diseases.[9] Diagnostic coronary angiography, PCI, MCS, acute organ failure, mechanical ventilation, and hemodialysis were identified for all admissions (Supplementary Table 2).[1,2,10,11] Early coronary angiography was defined as coronary angiography performed on day 0 of hospitalization.

The primary endpoint was in-hospital mortality and secondary endpoints included length of stay, hospitalization costs, discharge disposition, use of early coronary angiography, PCI, and MCS devices during this 15-year period. We also sought to define the 15-year temporal trends for hospitalizations for AMI-CS based on hospital characteristics.

As recommended by HCUP-NIS, survey procedures using discharge weights provided with HCUP-NIS database were used to generate national estimates. Using the trend weights provided by the HCUP-NIS, samples from 2000 to 2011 were reweighted to adjust for the 2012 HCUP-NIS redesign. Chi-square and *t* tests were used to compare categorical and continuous variables respectively. Adjusted temporal trends were calculated using multivariable hierarchical logistic regression analysis incorporating age, sex, admission year, primary payer status, socioeconomic stratum, comorbidities, acute organ failure, cardiac procedures, and noncardiac interventions, were performed for the prevalence of AMI in CS and in-hospital mortality in AMI-CS (referent year 2000). The inherent restrictions of the HCUP-NIS database related to research design, data interpretation, and data analysis were reviewed and addressed.[12] For the multivariate modeling, regression analysis with purposeful selection of statistically and clinically relevant variables was conducted. All values were presented as odds ratio (OR) with corresponding 95% confidence interval (CI). An a priori analysis was performed for weekend vs weekday admissions and in the individual cohorts of ST-elevation MI (STEMI) and non−ST-elevation MI (NSTEMI) among the hospital categories. Two-tailed p <0.05 was considered statistically significant. All statistical analyses were performed using SPSS v25.0 (IBM Corp, Armonk, NY).

Results

There were an estimated 9,747,034 admissions for AMI between 1 Jan 2000 and 31 Dec 2014, 362,065 (3.7%) constituted AMI-CS admissions among patients who did not require interhospital transfer. In the total cohort, 8.4% were admitted to rural hospitals, 44.8% to urban nonteaching hospitals and 46.8% to urban teaching hospitals. When stratified by hospital size, 8.2%, 23.3% and 68.5% were admitted to small, medium and large hospitals respectively. The trends in the frequency of AMI-CS over 15-years are presented in Figures 1. There was a significant increase

over time in admissions for AMI-CS across all hospital groups. The baseline characteristics of patients stratified by hospital characteristics are presented in Table 1. There was a steady increase in the use of early coronary angiography and PCI across all hospital categories during this 15-year period (Figure 2). There was a rise in the use of MCS in the earlier years of the study, but this plateaued in the latter half. Importantly, the use of these interventions was consistently lower in rural and smaller hospitals over the study duration (p <0.001 for trend).

In comparison to rural hospitals, the unadjusted in-hospital mortality was significantly lower in urban nonteaching (45.1% vs 39.7%, OR 0.81 [95% CI 0.78 to 0.82]; p <0.001) and teaching hospitals (45.1% vs 38.6%, OR 0.84 [0.81 to 0.87]; p <0.001). When stratified by hospital size, there was a serial decrease in mortality with increasing size. In comparison to smaller hospitals, medium hospitals (42.4% vs 40.8%, OR 0.94 [0.91 to 0.96]; p <0.001) and large hospitals (42.4% vs 39%, OR 0.87 [95% CI 0.84 to 89]; p <0.001) had lower mortality during the study period. The unadjusted and adjusted 15-year trends of in-hospital mortality in AMI-CS admissions stratified by hospital location, teaching status and bedsize are presented in Figure 3. The secondary outcomes are presented in Table 2. When stratified by hospital location/teaching status and bedsize, the in-hospital mortality was lowest in large urban teaching hospitals (38.4%), followed by large urban nonteaching hospitals (38.6%) and highest in small rural hospitals (54.3%).

In a multivariate analysis, use of early coronary angiography (adjusted OR 0.89 [95% CI 0.87 to 0.91]; p <0.001) and PCI (adjusted OR 0.55 [95% CI 0.54 to 0.56]; p <0.001) were associated with lower in-hospital mortality (Supplementary Table 3). Admission to an urban nonteaching hospital (adjusted OR 0.81 [95% CI 0.78 to 0.84], p <0.001) and urban teaching hospital (adjusted OR 0.87 [95% CI 0.84 to 0.91, p <0.001) were associated with lower mortality compared with rural hospitals, independent of patient demographics, baseline co-morbidity, organ failure and cardiac and noncardiac interventions (Supplementary Table 3). Evaluating hospitals by bedsize, in comparison to a small hospital, admission to a large hospital (adjusted OR 0.94 [95% CI 0.91 to 0.98); p = 0.002) but not a medium-sized hospital (adjusted OR 0.98 [95% CI 0.95 to 1.02]; p = 0.36) was associated with lower in-hospital mortality. This association remained unchanged in a supplemental analysis using restricted cubic spline transformations of age and year of admission.

The in-hospital mortality was similar on weekdays compared with weekends (rural 45.1% vs 45.1%, urban nonteaching, 39.7% vs 40.0%, urban teaching 38.7% vs 38.4%; small 42.6% vs 41.9%, medium 40.5% vs 41.6%, large 39% vs 38.8; all p >0.2). When stratified by type of AMI, STEMI-CS had lower in-hospital mortality in urban nonteaching (40.5%) and urban teaching (39.2%) hospitals vs a rural hospital (47.8%) (p <0.001). The in-hospital mortality for NSTEMI-CS was relatively similar across the various hospital categories (rural 38%, urban nonteaching 38%, urban teaching 37.5%; p = 0.01). When stratified by bedsize, there was a step-wise decrease in in-hospital mortality with increasing bedsize − STEMI-CS 44.5%, 42%, and 39.6% (p <0.001) but similar mortality in NSTEMI-CS
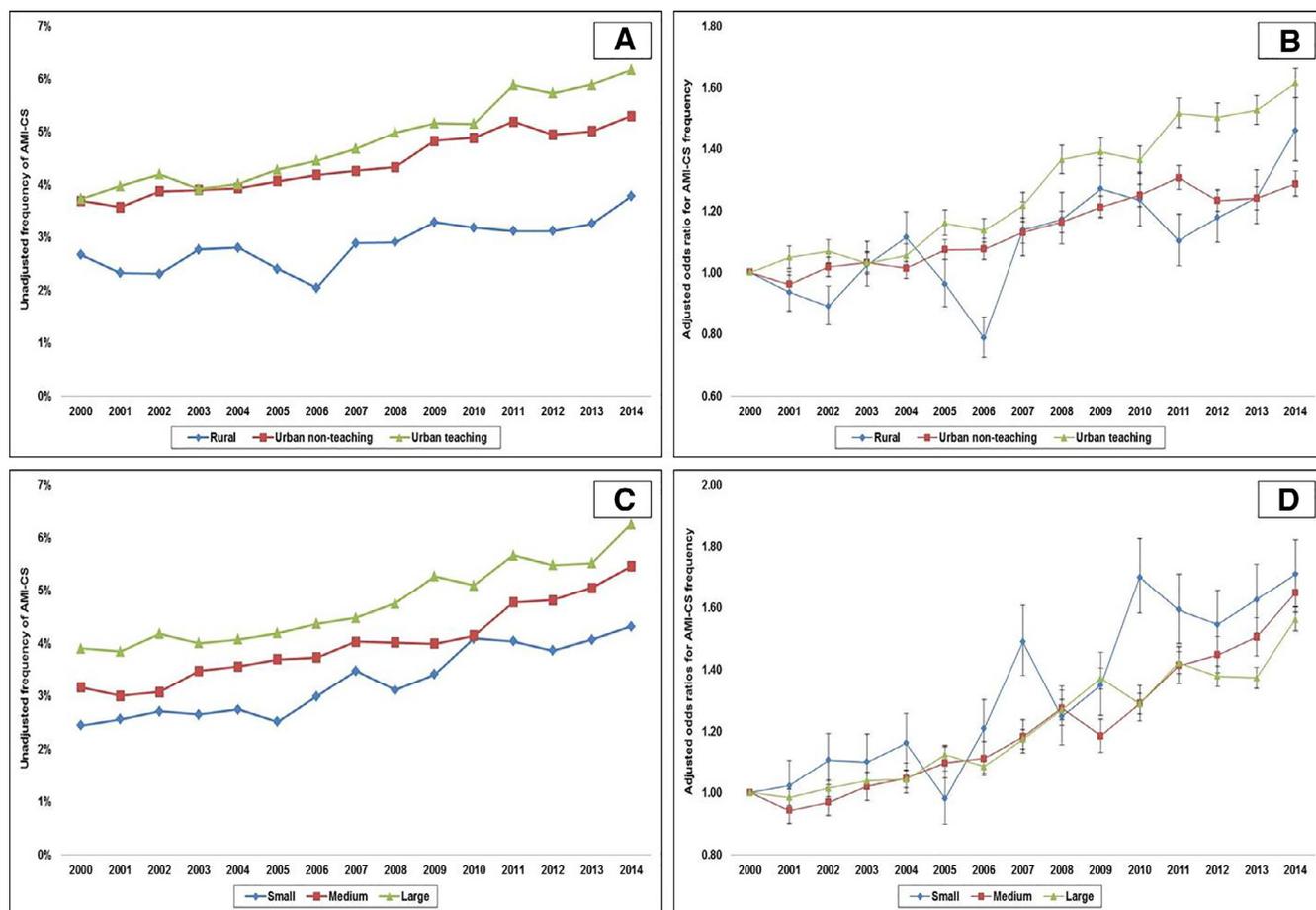
Figure 1. Unadjusted and adjusted 15-year temporal trends for the prevalence of AMI-CS stratified by hospital characteristics. *(A)* Unadjusted temporal trends of AMI-CS stratified by hospital location and teaching status; *(B)* Adjusted multivariate hierarchical logistic regression for temporal trends of AMI-CS stratified by hospital location and teaching status (referent year 2000); adjusted for age, sex, race, primary payer, socio-economic status, hospital region and co-morbidity; *(C)* Unadjusted temporal trends of AMI-CS stratified by hospital bedsize; *(D)* Adjusted multivariate hierarchical logistic regression for temporal trends of AMI-CS stratified by hospital bedsize (referent year 2000); adjusted for age, sex, race, primary payer, socio-economic status, hospital region and co-morbidity. AMI = acute myocardial infarction; CS = cardiogenic shock.

(38.4%, 38.3%, and 37.5%; p = 0.03) in small, medium, and large hospitals, respectively.

Discussion

The major findings of this study, from one of the largest cohorts of AMI-CS, are that there has been a significant increase in the use of early coronary angiography, PCI, and MCS across all hospital categories over the study duration. Use of early coronary angiography, PCI and MCS was greater in large and urban hospitals, and the use of early coronary angiography and PCI was associated with lower adjusted in-hospital mortality. There has been a steady decrease in mortality over time. Admission to an urban and a large hospital were independent predictors of decreased in-hospital mortality.

In patients with cardiovascular disease, the volume and outcome relationship appears to be related to both specific clinical diagnosis and procedure types.[13–17] PCIs performed at high-volume centers have 'safety nets' provided by the structure and processes independent of patient,

operator and procedural factors.[14] Furthermore, hospitals with the highest volumes are likely better equipped to perform emergency coronary angiography and PCI during off-hours.[18] Consistent with these data, we demonstrated that early coronary angiography was offered more commonly at large and urban hospitals and remained an independent predictor of decreased mortality in AMI-CS. Patients with AMI-CS need stabilization with intensive management to prevent the initial hemodynamic insult initiating metabolic failure.[2,19] Gonzalez et al. demonstrated that the volume-outcome effect in cardiac surgery is not due to decreased postoperative complications but rather due to "failure to rescue".[15] It is conceivable that urban and larger centers consistently use processes of care that facilitate early detection of complications and clinical deterioration, which is consistent with the findings of our study. In a meta-analysis of volume-outcomes relationship in critical illness, higher volume centers to have better overall outcomes.[17] Importantly, organizational factors and the presence of trained multidisciplinary teams could be contributing to improved outcomes independent of patient and disease-related

Table 1

Baseline characteristics of AMI-CS stratified by hospital characteristics.

Characteristic		Hospital location and teaching status				Hospital size			
		Rural (N = 29,692)	Urban non-teaching (N = 157,560)	Urban teaching (N = 164,813)	P	Small (N = 28,801)	Medium (N = 82,161)	Large (N = 241,104)	p
AMI type	ST-elevation	72.0%	69.7%	67.3%	<0.001	66.3%	68.5%	69.2%	<0.001
	Non-ST elevation	28.0%	30.3%	32.7%		33.7%	31.5%	30.8%	
Age (years)		73.1 ± 13.1	70.2 ± 13.1	68.7 ± 13.1	<0.001	72.0 ± 13.4	70.1 ± 13.2	69.4 ± 13.1	<0.001
Women		45.6%	39.9%	38.6%	<0.001	43.0%	40.3%	39.2%	<0.001
Primary payer	Medicare	74.5%	63.2%	59.6%	<0.001	67.6%	62.9%	61.7%	<0.001
	Medicaid	4.1%	5.5%	7.2%		5.5%	5.9%	6.4%	
	Private	14.5%	23.7%	24.8%		20.5%	23.4%	23.8%	
	Uninsured	3.9%	5.0%	5.4%		4.4%	5.0%	5.2%	
	No charge	0.1%	0.4%	0.5%		0.3%	0.4%	0.5%	
	Others	2.9%	2.2%	2.5%		1.7%	2.4%	2.5%	
Median household income (quartile)	0-25th	39.1%	18.3%	24.0%	<0.001	18.2%	21.8%	23.6%	<0.001
	26th-50th	39.3%	25.9%	23.4%		26.7%	25.3%	26.0%	
	51st-75th	16.9%	27.5%	25.2%		26.3%	25.5%	25.4%	
	75th-100th	4.6%	28.2%	27.5%		28.8%	27.4%	25.0%	
Hospital region	Northeast	13.9%	11.8%	22.7%	<0.001	24.9%	20.1%	15.1%	<0.001
	Midwest	28.4%	17.9%	26.4%		26.6%	21.2%	22.8%	
	South	46.9%	41.0%	35.6%		30.6%	38.1%	40.3%	
	West	10.9%	29.3%	15.3%		17.8%	20.5%	21.8%	
Charlson Comorbidity Index	0-3	18.0%	22.7%	25.5%	<0.001	19.7%	22.8%	24.3%	<0.001
	4-6	59.1%	55.6%	54.5%		55.9%	55.5%	55.3%	
	≥7	22.9%	21.7%	20.0%		24.3%	21.7%	20.4%	
Comorbidities	Hypertension	44.3%	50.9%	51.8%	<0.001	49.7%	51.6%	50.6%	<0.001
	Hyperlipidemia	25.3%	31.4%	32.6%	<0.001	29.6%	31.7%	31.6%	<0.001
	Diabetes mellitus	3.8%	4.6%	4.3%	<0.001	4.6%	4.7%	4.3%	<0.001
	Prior cancer	7.6%	7.1%	6.9%	<0.001	8.0%	7.1%	7.0%	<0.001
	Heart failure	53.0%	54.9%	55.5%	<0.001	55.6%	55.1%	54.9%	<0.001
Cardiac arrest		15.3%	18.9%	19.5%	<0.001	18.3%	19.4%	18.8%	<0.001
Invasive hemodynamic monitoring*		10.7%	16.9%	21.7%	<0.001	13.3%	16.4%	20.0%	<0.001
Mechanical ventilation		30.8%	41.6%	43.5%	<0.001	39.0%	41.6%	41.9%	<0.001
Hemodialysis		1.3%	3.0%	3.6%	<0.001	2.5%	2.7%	3.3%	<0.001

Represented as percentage or mean ± standard deviation; *pulmonary artery catheterization or right heart catheterization.

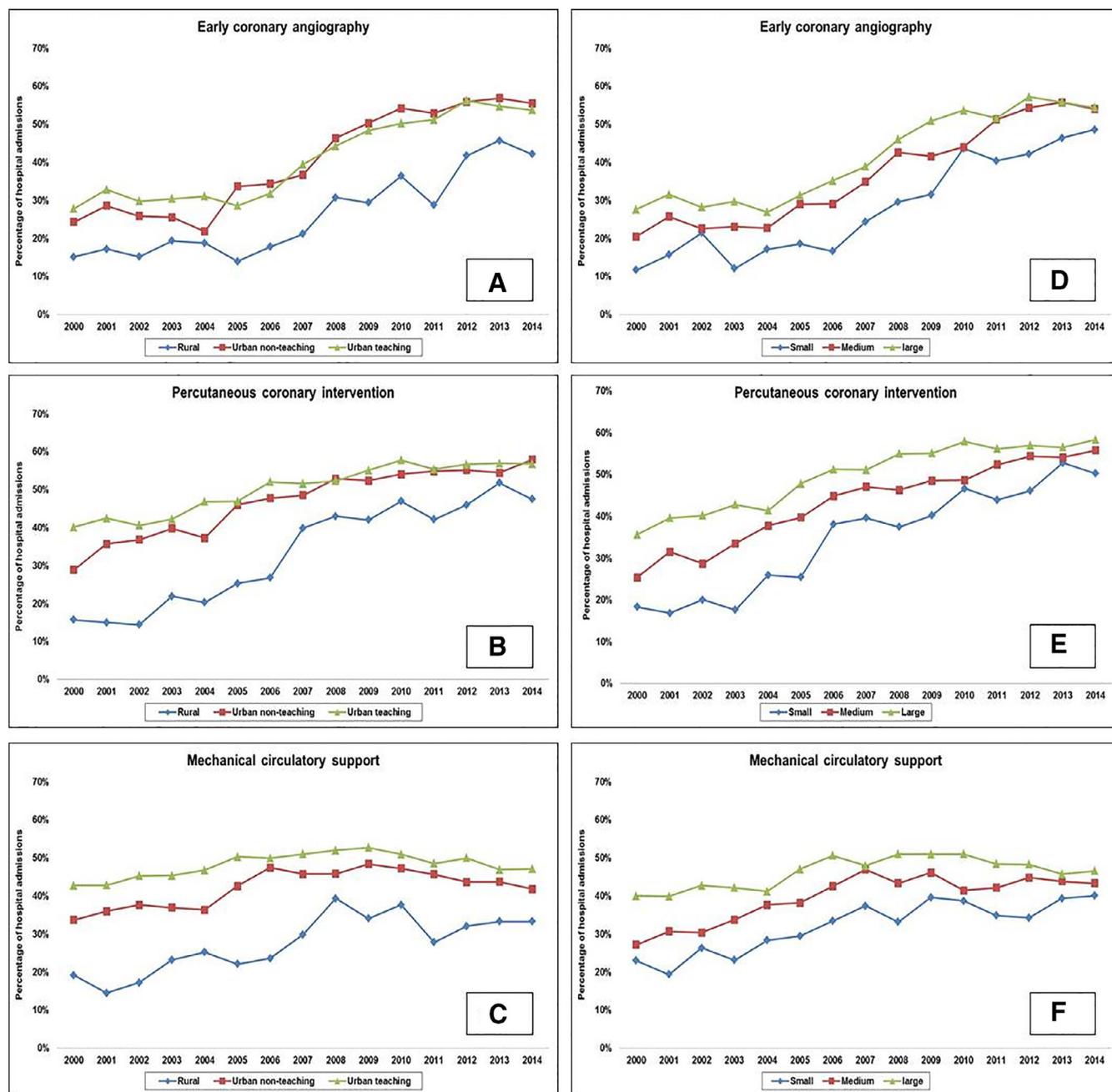AMI = acute myocardial infarction; CS = cardiogenic shock.

Figure 2. Fifteen-year temporal trends in cardiac procedures in AMI-CS by geographic regions. Fifteen-year trends of early coronary angiography (hospital day zero) *(A and D)*, percutaneous coronary intervention *(B and E)*, mechanical circulatory support *(C and F)* in AMI-CS stratified by hospital location/teaching status and bedsize; all p <0.001 for trend. AMI = acute myocardial infarction; CS = cardiogenic shock.

factors.[17] Such teams utilize multidisciplinary input regarding timing of angiography and PCI, use of MCS prior to or after PCI, and invasive hemodynamic monitoring, all of which may be associated with improved outcomes.[20–22] In addition to development of multidisciplinary care, identifying and eliminating barriers such as insurance differences, development of a hub-and-spoke referral pattern system with uniform protocols might aid in delivering more equitable care to this critically ill population.

Our study demonstrates higher multiorgan failure, use of cardiac and noncardiac interventions and greater discharges

to home from larger and urban centers. The adjusted OR for in-hospital mortality and length of stay were higher in urban teaching centers compared with urban nonteaching centers, which may be attributable to the higher acuity of patients seen in the teaching centers, however further granular data are needed to understand this phenomenon better. Likewise, the shorter length of stay in the rural hospitals might reflect earlier in-hospital mortality in this population. Furthermore, long travel distances in rural hospitals may significantly delay PCI and appropriate MCS use resulting in worse outcomes. In such cases, development of a hub-
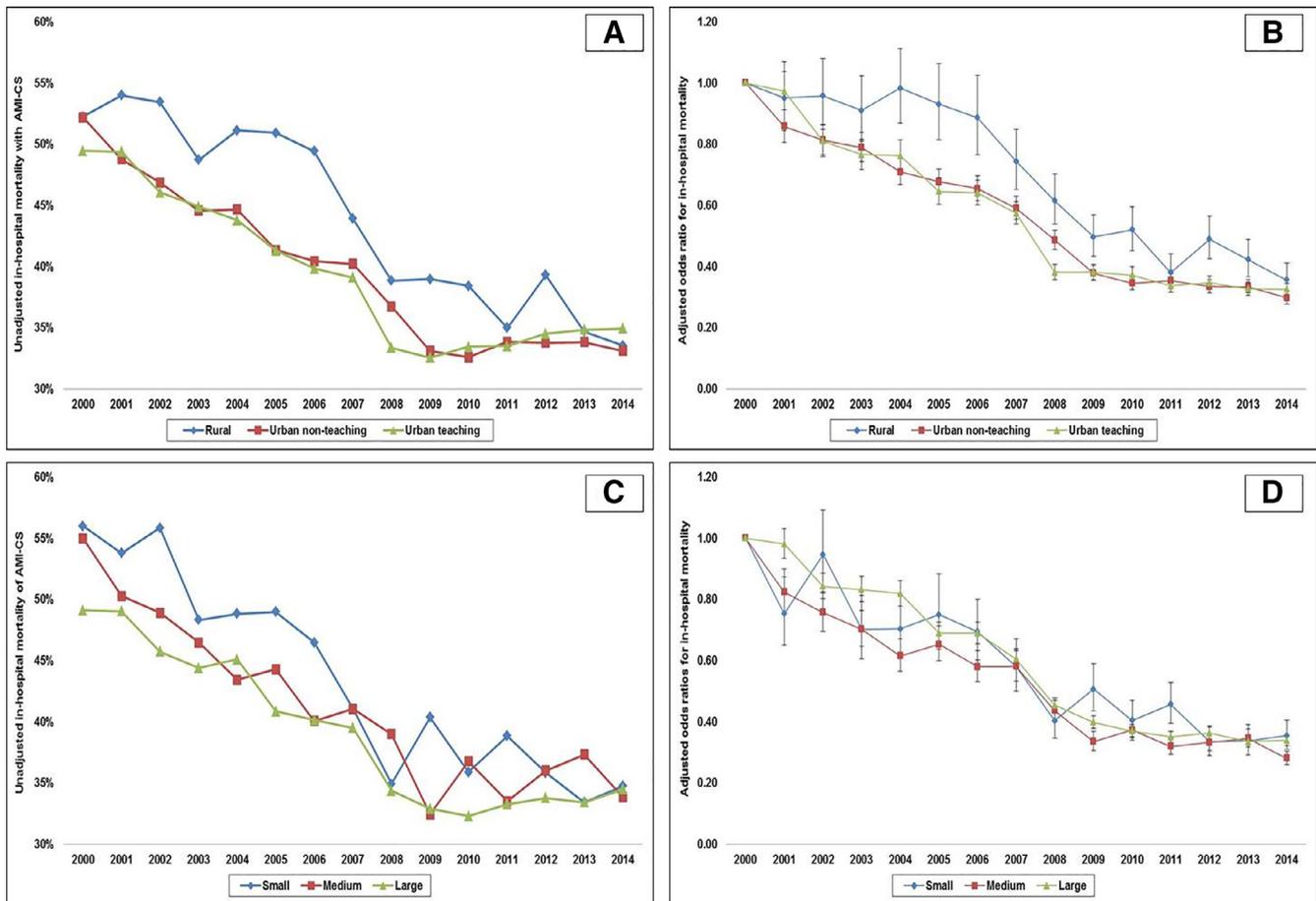
Figure 3. Unadjusted and adjusted 15-year temporal trends for in-hospital mortality in AMI-CS stratified by hospital characteristics. *(A)* Unadjusted temporal trends of in-hospital mortality in AMI-CS stratified by hospital location and teaching status; *(B)* Adjusted multivariate hierarchical logistic regression for in-hospital mortality temporal trends stratified by hospital location and teaching status (referent year 2000); adjusted for age, sex, race, primary payer, socio-economic status, hospital region, co-morbidity, acute organ failure, cardiac arrest, coronary angiography, percutaneous coronary intervention, invasive hemodynamic monitoring, mechanical circulatory support, invasive mechanical ventilation, hemodialysis; *(C)*: Unadjusted temporal trends of in-hospital mortality in AMI-CS stratified by hospital bedsize; *(D)* Adjusted multivariate hierarchical logistic regression for in-hospital mortality temporal trends stratified by hospital bedsize (referent year 2000); adjusted for age, sex, race, primary payer, socio-economic status, hospital region, co-morbidity, acute organ failure, cardiac arrest, coronary angiography, percutaneous coronary intervention, invasive hemodynamic monitoring, mechanical circulatory support, invasive mechanical ventilation, hemodialysis. AMI = acute myocardial infarction; CS = cardiogenic shock.

and-spoke model analogous to that used in cardiac arrest might be useful in decrease time from onset to first medical contact.[23] Our findings and that of others support recent advocacy for regionalization of CS care.[4,5] However, CS due to AMI compared with other etiologies such as postcardiotomy or end-stage heart failure, represent different populations, and thereby may be subject to significant differences in onset and clinical course.[24] Regionalized systems of care have been shown to improve adherence to best practices, deliver medical and procedural therapies more efficiently, and have superior management of complications for acute cardiac conditions such as STEMI and cardiac arrest.[25,26] In addition to regionalization the development of outreach teams, that is, mobile CS teams, have demonstrated encouraging results.[27]

This study has several limitations, some of which are inherent to the analysis of a large administrative database. The HCUP-NIS attempts to mitigate potential errors by using internal and external quality control measures. Given the moderate sensitivity of the administrative code for

CS, it is possible that less severe AMI-CS admissions were missed which could result in overestimation of acuity in this studied population.[2] It is important to note that patients who are transferred between hospitals may significantly differ from those that are not.[28,29] Prior work in AMI and critical illness has shown that younger patients with lower comorbidities are transferred more frequently.[28,29] It is possible that the patients at rural/small hospitals that were not transferred were inherently different and this could impact outcomes observed. However, in patients with AMI there were no notable differences between outcomes at rural and urban population.[28] Further work on defining standardized criteria for inter-hospital transfers in AMI-CS is needed.[5] Importantly, the onset of CS with respect to AMI cannot be reliably ascertained from this administrative database and so early coronary angiography might not be an appropriate metric in this population.

In conclusion, admission to a large and urban hospital is associated with higher use of early coronary

Table 2
Primary and secondary end-points of AMI-CS stratified by hospital characteristics.

Characteristic	Hospital location and teaching status				Hospital size			
	Rural (N = 29,692)	Urban non-teaching (N = 157,560)	Urban teaching (N = 164,813)	p	Small (N = 28,801)	Medium (N = 82,161)	Large (N = 241,104)	p
In-hospital mortality	45.1%	39.7%	38.6%	<0.001	42.4%	40.8%	39.0%	<0.001
Length of stay (days)	6.4 ± 6.9	8.7 ± 9.3	10.6 ± 12.0	<0.001	7.8 ± 9.2	8.6 ± 9.7	9.9 ± 11.0	<0.001
Hospitalization costs (×1000 USD)	51 ± 67	116 ± 135	134 ± 159	<0.001	88 ± 112	108 ± 134	126 ± 151	<0.001
Discharge disposition								
Home	34.4%	41.8%	44.8%	<0.001	35.2%	39.8%	44.5%	<0.001
Short-term hospital	28.8%	15.1%	8.0%		21.3%	16.9%	10.5%	
Skilled nursing facility	25.5%	27.7%	29.8%		30.7%	29.1%	28.1%	
Home with HHC	11.2%	15.1%	17.2%		12.6%	14.0%	16.7%	
Early coronary angiography (day 0)	25.1%	40.1%	42.5%	<0.001	30.3%	38.0%	41.8%	<0.001
Percutaneous coronary intervention	31.3%	46.7%	51.1%	<0.001	36.6%	44.1%%	49.9%	<0.001
Mechanical circulatory support								
Total	26.6%	42.1%	48.2%	<0.001	32.9%	39.7%	46.3%	<0.001
IABP	26.1%	41.5%	46.7%	<0.001	32.2%	38.8%	45.2%	<0.001
pLVAD	0.6%	0.8%	1.7%	<0.001	0.6%	1.1%	1.3%	<0.001
npMCS	0.3%	0.2%	0.5%	<0.001	0.3%	0.2%	0.4%	<0.001
ECMO	0.1%	0.1%	0.7%	<0.001	0.1%	0.2%	0.4%	<0.001

Represented as percentage or mean ± standard deviation.

AMI = acute myocardial infarction; CS = cardiogenic shock; ECMO = extracorporeal membrane oxygenation; HHC = home health care; IABP = intra-aortic balloon pump; npMCS = nonpercutaneous mechanical circulatory support; pLVAD = percutaneous left ventricular assist device; USD = United States Dollars.

angiography, lower in-hospital mortality, and greater likelihood of discharge to home. These data suggest that hospital-level disparities exist in the management and outcomes of AMI-CS which are not fully accounted for differences in patient characteristics. The potential disparity in healthcare delivery in this high-risk population hence represents a significant opportunity for targeted improvement in application of advanced, evidence-based therapies. Given the inherent limitations of this retrospective administrative database, dedicated prospective studies are needed to further health care policy research on regionalization of CS care.

Disclosures

The authors have no conflicts of interest to disclose.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2019.05.038.

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